while lower frequencies in the range of .1 to .5 megahertz are suitable for larger conduits.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will be understood from the description of illustrative embodiments below, taken in together with the Figures, wherein:

Figure 1 illustrates a prior art tag measurement system;

Figure 2 illustrates a tag measurement system of the present invention;

Figures 2A-~~2B~~ 2E illustrate chordal tag measurement systems;

Figures 3A and 3B illustrate signal paths and different driving arrangements for the system of Figure 2;

Figure 4 illustrates a processor used in the system of Figure 2;

Figure 5 show a table of tag measurements made in a prototype system of the present invention; and

Figure 6 illustrates range, repeatability and comparability of measurements made with the present invention and with the prior art.

DETAILED DESCRIPTION

Figure 1 illustrates a prior art transducer arrangement and signal path in a clamp-on tag flow meter arrangement 10. As shown, a first transducer pair T1, R1 attaches to a conduit 4 to launch the transducer signal denoted S_{T1} such that the fluid-borne portion of the signal crosses the fluid at a defined path angle θ_3 on path P1, and a second transducer pair, T2, R2 is positioned offset a distance L along the flow stream to define second fluid path P2 for a transmitted signal S_{T2}. P2 is located parallel to, and a short but fixed or known distance along the conduit from, path P1. Thus, for entrained scatterers in a well behaved flow, the signal modulation produced by a given set of tags will be substantially identical at the two different times when that set of tags pass through the respective beams. Apart from profile considerations, flow velocity v is then given by this time interval (τ) and the path spacing L, namely $v = KL/\tau$, where K is a meter factor that takes into account the flow profile and the manner in which the sound beams interact with the flow along the paths. In most cases θ_3 is small -

serial superposition of an endless stream of individual cycles from a continuous source of sine waves.

In an application such as air in a steel pipe, the mismatch of acoustic impedance is so great that the wave introduced by transducer T1 primarily stays in the pipe and reradiates many times into the fluid before the energy is totally dissipated. This is illustrated conceptually n FIG. 2C. The wave incident from T1 at incident angle θ_1, in a plane perpendicular to the pipe, gives rise to a first refracted ray at refracted angle θ_3 and that ray proceeds tangent to a construction circle of reduced radius R_{cc}. The broken-line path zigzagging around the pipe radiates another ray which typically will also be tangent to the same construction circle, or to one of similar radius. This zigzag model is well known and may be found in patents by Brazhnikov, or by Lynnworth and others, or elsewhere in the technical literature. The chordal paths in FIGS. 2A, 2B thereby interact primarily with eddies or turbulence outside the construction circle, i.e. they exclude a core, while the diameter paths of FIG. 2 interact with the core too. Thus the two interrogations may complement one another and may be used to define the proper meter factor K.

Another characteristic of the chordal paths of FIGS. 2A, 2B is that, in end view, the transducers can all be on one side of the pipe and are contained within a narrow arc corresponding to the angle θ_x in Fig 2D. The subtended angle θ_x is less than or equal to 60° and preferably is less than or equal to 30°. Conduit 200 may be a steam pipe of a building heating system or a process feed gas pipe of a chemical plant. See Fig. 2E.

By employing anti-parallel paths between the respective pairs of transmitter and receiver, the crosstalk from one transmitter reaching the receiver of the other path consists entirely of signal passing through the wall of the conduit, and has no contribution or a greatly reduced coherent component in the relevant time window that has crossed the fluid path or encountered the scatterers of interest for a tag correlation measurement. This situation is illustrated in Figure 3A where the cross talk signal S_{T12} from transmitter T1, and the cross talk signal S_{T12} from transmitter T2 are each shown propagating along the pipe wall to an adjacent receiver of the opposite path. The tag correlation measurement depends on the presence of scatterers, and it is immaterial